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Original Research Article

Measuring and Analyzing the Impact of Technological Changes on Chinese Commodity Exports (2000-2022) Using the Threshold Regression Model

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Abstract: Technological changes and trade are closely intertwined in the contemporary era. Technological advancements, particularly in the realms of communications, information technology, and patents, have played a crucial role in stimulating and reshaping international trade by influencing production methods and the quality of goods and services produced. This research aims to analyze and measure the impact of technological changes, represented by patent applications, on commodity exports in China. Employing the Threshold Regression model, the study examines the magnitude of this impact across various stages during the research period. The underlying hypothesis posits a positive correlation between technological changes and commodity exports in China throughout these different stages. To achieve this objective and validate the hypothesis, the research combines two methodological approaches. The deductive approach utilizes descriptive analysis in the theoretical framework, drawing upon economic theory and a comprehensive review of literature pertaining to technological changes and foreign trade. Conversely, the inductive approach employs quantitative analysis, leveraging econometric techniques to interpret the relationship between technological changes and foreign trade. The study relies on time series data spanning the period from 2000 to 2022. Following a series of econometric tests, the data was deemed suitable for analysis using the Threshold Regression model. The results of the Bai-Perron sequential test for threshold values revealed the existence of five thresholds for the dependent variable (patent applications) when testing for multiple structural breaks. The impact of these thresholds on commodity exports was positive and statistically significant across all five thresholds, with the greatest impact observed at the first threshold, followed by a gradual decline until reaching saturation levels in the subsequent thresholds. Based on these findings, the research recommends that Chinese authorities conduct periodic analyses of the impact of patents on exports across all stages. Furthermore, it suggests adjusting strategies at each stage based on the results to ensure the continued positive impact of patents on commodity exports.

Keywords: Technological Changes, Commodity Exports, Threshold Model.

INTRODUCTION

In recent decades, China has witnessed rapid and remarkable developments and transformations in the field of technology. Technological changes have become an integral part of its growth process. Since the beginning of the new millennium, Chinese authorities have adopted strategies to promote and develop the technology sector by increasing expenditure on research and development. The country has embarked on an accelerated path toward technological advancement, particularly in digital technology, artificial intelligence, smart manufacturing, renewable energy, and the met averse economy. Technological changes have contributed to radical and positive shifts in the Chinese economy, driving and bolstering economic growth and enhancing global competitiveness, especially in the foreign trade sector, particularly exports, which are the primary engine of its economic growth. By tracking the volume of Chinese commodity exports, based on World Bank data, it is evident that they have increased significantly during the research period. After surpassing the threshold of $6 trillion in 2000, they accelerated to exceed $25 trillion in 2022. This acceleration underscores the tremendous developments in the volume of Chinese exports and their ability to compete globally, highlighting how technological changes have contributed to the doubling of export volume and increased competitiveness. Understanding technological changes and their implications for Chinese exports is of paramount importance. Hence, this research sheds light on these variables and measures the relationship between them during the research period using the Threshold Regression model.

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Research Problem

Despite China's rapid strides in technology to enhance its competitiveness, it remains in a race with developed countries in this field, such as the United States, European countries, and the Asian Tigers. In this context, the research problem can be formulated as follows: To what extent do ongoing technological changes in China impact the external competitiveness of its commodity exports?

Research Objective

This research aims to investigate the relationship between technological changes and Chinese exports, and then to measure this relationship using the Threshold Regression model to determine the magnitude of the impact across various periods within the research timeframe.

Research Significance

The significance of this research lies in its focus on a prominent contemporary economic issue: technological change and its impact on the competitiveness of commodity exports. This is a subject in which all countries are vying for a leading position. Given China's pioneering experience in this field, it has been chosen as the focus of this study.

Research Hypothesis

This research operates under the hypothesis that there is a positive relationship and impact between technological changes and commodity exports in China across all stages within the research period.

RESEARCH METHODOLOGY

This research employs a deductive approach, utilizing descriptive analysis in the theoretical framework. This is supported by economic theory and a comprehensive review of literature pertaining to technological changes and foreign trade. Furthermore, an inductive approach is employed through quantitative analysis, leveraging econometric methods to interpret the relationship between technological changes and foreign trade.

Research Structure

To achieve the research objective and test the hypothesis, the study is divided into three sections. The first section presents a literature review. The second section focuses on technological changes, commodity exports, and the relationship between them. The third section utilizes the Threshold Regression model to measure the relationship between technological changes and commodity exports.

Section One: Literature Review

Numerous studies have examined the topic of technology and trade, focusing on the role of technology in developing foreign trade and increasing the international competitiveness of domestic exports. Some of these studies include:

- Abdel Fattah (2017), "The Impact of Research and Development Embodied in International Trade on Employment": This study, conducted on the countries of the Organization for Economic Co-operation and Development (OECD) for the period 2000-2010, concluded that technology transferred through imports to these countries has contributed to the implementation of innovations, the development of new products, and subsequently, job creation and a reduction in unemployment rates. However, the indirect effects of technology through exports have negatively impacted job creation as they increase the need for innovation to keep pace with global markets.

- Nour El-Din (2018), "Digital Economy and Foreign Trade": Focusing on the Arab world, this study analyzed indicators of the digital economy and e-commerce in some Arab countries. It concluded that there is a weakness in digital economy indicators and their reflection on foreign trade when compared to the rest of the world.

- Han-Wei Liu and Ching-Fu Lin (2020), "Artificial Intelligence and Global Trade Governance: A Pluralist Agenda": This study highlighted the impact of technological changes on global trade under the rules and regulations of the World Trade Organization (WTO). It emphasized the need for flexibility in WTO rules and regulations to keep pace with rapid technological changes. Conversely, the global trading system should be more respectful of local values, customs, and cultures. If this is achieved, technological changes will have a greater impact on global trade.

-Musa (2022), "The Impact of Information and Communication Technology on the Sustainability of E-commerce: Experiences of Selected Countries with an Attempt to Benefit from them in Iraq for the period (2013-2020)": This study focused on the United States and the United Arab Emirates, comparing them with Iraq using descriptive and analytical methods. The study found that there is development in the technology and information sector in the United States and the United Arab Emirates, and this development has been positively reflected in increasing the volume of e-commerce. However, for Iraq, the results indicated weakness in e-commerce compared to the study sample, due to the backwardness and weakness of technology sector indicators.

-Touati and Aljazea (2023), "The Impact of Information and Communication Technologies on International Trade: The Case of MENA Countries": This study, conducted on the Middle East and North Africa region using panel data for the period (2005-2019), used the Information and Communication Technology Development Index (IDI), a composite index that combines 11 sub-indices representing explanatory variables, with information technology exports and imports as dependent variables. This study

concluded that there is a statistically significant negative impact of information technology on exports and a statistically significant positive impact on imports.

-Al-Aswad (2024), "Measuring and Analyzing the Effectiveness of Spending on Research and Development in the Growth of High-Tech Exports (Singapore as a Model)": This study used expenditure on research and development as an indicator of technology and exports as an indicator of foreign trade. The study relied on the ARDEL model to measure the relationship between them and concluded that increased spending on research and development contributed to the growth of technology exports in Singapore.

Finally, it is important to highlight the scientific contribution of this research. In addition to addressing the important and vital topic of technological changes in the modern era and their relationship to Chinese commodity exports, this research is unique in its use of a modern statistical model not used by studies that have addressed this topic, namely the Threshold Regression model. This model is of great importance in economic studies because it measures the relationship between the studied variables at different stages during the research period and identifies the points at which significant changes occur in the relationship between the variables. This allows economic policymakers to change plans and make appropriate decisions at each stage of the research, ensuring the continued positive impact of independent variables on the dependent variable(s).

Section Two: Technological Changes, Commodity Exports, and the Relationship Between Them

First: Technological Changes

Technological change refers to the introduction of new ideas or the improvement of existing methods to develop new technologies. It also encompasses the application of modern technologies like artificial intelligence and virtual reality in various fields such as commerce, industry, services, agriculture, and other sectors, ensuring continuous development.

Several concepts of technological change have emerged. It can be defined as the processes that lead to the development or improvement of available technology. It also refers to changes in the methods of designing and manufacturing technology. In the modern era, technology has permeated all aspects of life, including economic aspects, such as developments in economic variables like gross domestic product, trade, investment, production, unemployment, and others.

It has also encompassed social aspects, such as changes in lifestyle and human relationships. Furthermore, it has extended to environmental aspects, such as the use and application of technology for the optimal utilization of natural resources and the achievement of sustainable development. Technological changes are even used in the fields of politics and law, such as intellectual property rights, cybersecurity, and privacy (Abdul Karim & Khalaf, 2023, p. 172).

The 21st century has witnessed a decisive shift in economic policies and economic development plans and strategies due to the tremendous technological revolution and the belief of countries around the world that technology is the main driver of economic growth and strengthens the ability of countries and companies to compete globally.

Second: Commodity Exports

Commodity exports represent a vital foundation and backbone of the global economy. They refer to the process of selling domestically produced goods and products to the outside world. Commodity exports are a fundamental aspect of foreign trade that contributes to strengthening and developing local economies. Due to the importance of commodity exports in providing the necessary funds to finance development in countries participating in foreign trade, all countries involved in foreign trade have sought to effectively develop and enhance their commodity exports and increase access to global markets with the aim of promoting economic growth and achieving sustainable development. In general, the economic importance of commodity exports can be summarized as follows (Shihab *et al.*, 2021, pp. 95-96):

1. **Achieving economic growth:** Commodity exports contribute to increasing the gross domestic product of exporting countries, as they contribute to increased production and revenues and provide new job opportunities.
2. **Diversifying sources of income:** Commodity exports are a major source of national income, which can reduce the economy's dependence on other sectors such as services or tourism.
3. **Improving the trade balance:** Commodity exports contribute to improving the trade balance of countries participating in foreign trade. Increasing exports while keeping imports constant improves the trade balance.
4. **Increasing competitiveness:** Commodity exports help enhance the competitiveness of local products, encourage innovation, and improve product quality according to international standards to meet the requirements of foreign markets.
5. **Creating opportunities for foreign direct investment:** Commodity exports are a source of attraction for foreign direct investment, as exporting products is linked to international supply, distribution, and marketing networks, which encourages the establishment of new partnerships and investments. If countries participating in foreign trade want to create new opportunities for investment, they must take a set of measures that can be identified as follows (Al-Dabbagh, 2005, pp. 179-180):

- **International advertising and marketing:** Countries participating in foreign trade use digital

marketing tools such as creating websites in multiple languages, participating in international exhibitions, or even using social media platforms. The goal is to raise awareness, create a positive impression of exported products, and attract international customers.

- **Improving the quality and efficiency of local products:** This is achieved by applying global quality standards to local products to comply with the requirements of foreign markets. This creates a positive impression among foreign consumers about the local product, which contributes to increasing export volume.
- **Product diversification:** Diversifying products helps reduce potential economic risks if the country relies on a single product for export. This situation applies to rentier economies, especially oil-producing countries, which are more vulnerable to fluctuations.
- **Diversification of foreign markets:** The country participating in foreign trade must search for new markets to provide opportunities for growth and expansion in export volume.
- **Improving the quality of logistical infrastructure:** The quality of infrastructure such as transportation, storage, and distribution helps enhance the ability of local companies to meet the requirements of foreign markets.
- **Investing in technology:** The use of modern technology such as the internet and artificial intelligence can contribute to improving productivity and product quality, thus increasing competitiveness and opening up new export opportunities.

Third: The Relationship Between Technological Changes and Commodity Exports

Technological changes have contributed to enhancing the competitiveness of exports of countries participating in foreign trade. By tracking export volumes based on data issued by the World Bank or local statistical bulletins of countries participating in foreign trade, we observe that countries with a larger share of global exports occupy advanced positions in technology-related indicators. This indicates the interconnectedness and positive relationship between technological changes and exports (The World Bank, 2024). The relationship between technological changes and exports is not new. However, the tremendous developments and the accelerating technological revolution in the 21st century have made technology the primary influencer of the volume and competitiveness of exports globally. Referring to economic theory, we find that the classical theory of economic growth emphasized the crucial role of technology in achieving sustainable growth. Through technology, countries can improve the efficiency and quality of their products, which enhances their ability to export their products at competitive prices and quality. Keynesians also emphasized this role, and the theory of economic integration has shown the role of technology in enhancing production and reducing costs. Technology contributes to the emergence of innovation, the development of new products, and the expansion of the range of exported goods and their competitiveness. This was not limited to the classics and Keynesians; rather, the theories that came after them emphasized this matter, such as the theory of innovation and forward transfer in 1961 by Solow, who won the Nobel Prize in Economics in 1987, the theory of technological improvement, the theory of crystalline technological capability, the technological gap, and the theory of technological disparity (Dhanoon, 2020, pp. 93-95).

The Relationship Between Technological Change and Foreign Trade in the Modern Era

The relationship between technological change and foreign trade has become more effective and impactful in the present time. This impact is clearly evident through several avenues, including e-commerce, which has become an integral part of commercial activity. Individuals and companies can now conduct buying and selling transactions over the internet through mobile phones and dedicated shopping websites and platforms like Amazon. Artificial intelligence has also contributed to strengthening the relationship between technology and foreign trade through its ability to analyze big data. This helps producers and companies understand individual behaviors and desires, enabling them to develop products that align with the tastes of consumers abroad, positively impacting production and exports. It is also important to highlight the role played by digital currencies, particularly blockchain technology, in facilitating and increasing trade exchange. This technology provides secure and transparent levels of settlement for payments resulting from trade exchange (Songwe, 2019, pp. 27-28). Based on the foregoing, it can be said that technological changes have effectively contributed to doubling the volume of trade exchange globally. Consequently, countries around the world are witnessing competition in the field of technology to strengthen their economies and develop their foreign trade.

Section Three: Utilizing the Threshold Regression Model to Measure the Relationship Between Technological Changes and Commodity Exports

First: Research Variables

1. **Dependent Variable (Commodity Exports):** The value of Chinese commodity exports, referring to the value of goods exported to the rest of the world, estimated in current US dollars.
2. **Independent Variable (Technological Changes):** Technological changes are represented by the Patent Applications Index. These are patent applications filed in China through the Patent Cooperation Treaty or with one of the national patent offices to register exclusive ownership of an innovation, whether it is a new product, an improvement to an existing product, or a new technical solution to a problem. Patents provide protection for the invention for the

benefit of the patent holder for a limited period, which may reach up to 20 years (The World Bank, 2024, https://data.albankaldawli.org/indicator).

Second: Mathematical Formulation of the Model

The double-logarithmic model is utilized, and the equation is as follows:

$Log(Y) = B_0 + B_1 Log(X) + u_i$

Third: Unit Root Test

To ensure the absence of the unit root problem, the KPSS test, which is used for small samples, was conducted. The test results indicated that the dependent variable (Y) is stationary at the level, as well as the independent variable (X). This means that they do not have a unit root, i.e., they are stationary. It is noted that all variables are stationary, whether without a constant or with a constant and trend or without a constant and trend, and at a significance level of (1-5-10%). See Table (1).

Table (1) Unit Root Test (KPSS)

UNIT ROOT TEST RESULTS TABLE (KPSS)			
Null Hypothesis: the variable is stationary			
	At Level		
		LOG(Y)	LOG(X)
With Constant	t-Statistic	0.6339	0.6605
	Prob.	**	**
With Constant & Trend	t-Statistic	0.1698	0.1726
	Prob.	**	**
Without Constant & Trend	t-Statistic	=======	=======
	Prob.		

**** Significance Level (5%)**

Source: Prepared by the researcher based on the statistical software (EViews, 12)

Determining the Model Threshold

Determining the model threshold aids in analyzing economic data. According to Table (2), which displays the results of the Bai-Perron sequential test for threshold values, and when comparing the test results based on the F-statistic, the calculations used in determining the thresholds are shown. The test results indicated rejection of the null hypothesis (H0), which suggests the absence of thresholds. Conversely, the results confirmed the non-rejection of the alternative hypothesis (H1), indicating the presence of five thresholds for the dependent variable (Y) when testing for multiple structural breaks.

Table (2) - Bai-Perron Tests.

Multiple threshold tests			
Bai-Perron tests of L+1 vs. L sequentially determined thresholds			
Sequential F-statistic determined thresholds: 5			
		Scaled	**Critical**
Threshold Test	**F-statistic**	**F-statistic**	**Value****
0 vs. 1 *	47.53403	95.06807	11.47
1 vs. 2 *	99.1401	198.2802	12.95
2 vs. 3 *	13.0221	26.0442	14.03
3 vs. 4 *	7.9594	15.9188	14.85
4 vs. 5 *	34.0666	68.13321	15.29
* Significant at the 0.05 level.			
** Bai-Perron (Econometric Journal, 2003) critical values.			
Threshold values:			
	Sequential	**Repartition**	
1	13.99917	13.29349	
2	13.29349	14.01473	
3	14.76714	14.45651	
4	14.45651	14.60805	
5	14.60805	14.76714	

Source: Prepared by the researcher based on the statistical software (EViews, 12)

Fifth: The Impact of Technological Changes on Chinese Commodity Exports

The results revealed that the coefficient of determination explains 99% of the changes in commodity exports in China as a result of changes in technology through patents, with 1% attributed to factors outside the standard model, such as random variables. The results also showed that the F-statistic is significant at the 5% significance level. Therefore, the model is statistically significant and suitable for prediction. The

data was divided into five periods or thresholds based on the values of the dependent variable. The results can be interpreted economically as follows:

1. **First Threshold (N=4):** When the commodity export rate is less than LOG(Y) < 13.29349, the relationship is positive. The impact of patents (independent variable) on the dependent variable (commodity exports) is 0.714. This means that for every 1% increase in patents in China, commodity exports increase by 0.714% at a 1% significance level.
2. **Second Threshold (N=4):** When the commodity export rate in China is 13.29349 <= LOG(Y) < 14.01473, the relationship is positive. The impact of patents (independent variable) on the dependent variable (commodity exports) is 0.563. This means that for every 1% increase in patents in China, commodity exports increase by 0.563% at a 1% significance level.
3. **Third Threshold (N=3):** The relationship is positive when the commodity export rate in China is 14.01473 <= LOG(Y) < 14.45651. The impact of patents (independent variable) on the dependent variable (commodity exports) is 0.378. This means that for every 1% increase in patents in China, commodity exports increase by 0.378% at a 1% significance level.
4. **Fourth Threshold (N=3):** The relationship is positive when the commodity export rate in China is 14.45651 <= LOG(Y) < 14.60. The impact of patents (independent variable) on the dependent variable (commodity exports) is 0.070. This means that for every 1% increase in patents in China, commodity exports increase by 0.07% at a 1% significance level.
5. **Fifth Threshold (N=6):** The relationship is positive when the commodity export rate in China for this threshold is 14.60805 <= LOG(Y) < 14.76714. The impact of patents (independent variable) on the dependent variable (commodity exports) is 0.128. This means that for every 1% increase in patents in China, commodity exports increase by 0.128% at a 1% significance level. See Table (3).

Table (3) Estimating the Impact of Technological Changes on Chinese Commodity Exports

Dependent Variable: LOG(Y)				
Method: Discrete Threshold Regression				
Date: 07/11/24 Time: 23:17				
Sample: 2000 2022				
Included observations: 23				
Selection: Trimming 0.15, Max. thresholds 5, Sig. level 0.05				
Threshold variable: LOG(Y)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LOG(Y) < 13.29349 -- 4 obs				
C	5.150919	0.508737	10.12491	0.000
LOG(X)	0.71442	0.048073	14.86129	0.000
13.29349 <= LOG(Y) < 14.01473 -- 4 obs				
C	7.085288	0.866571	8.176234	0.000
LOG(X)	0.563979	0.075425	7.477325	0.000
14.01473 <= LOG(Y) < 14.45651 -- 3 obs				
C	9.521999	0.735759	12.94174	0.000
LOG(X)	0.378526	0.060015	6.307166	0.0001
14.45651 <= LOG(Y) < 14.60805 -- 3 obs				
C	13.47204	0.298484	45.13489	0.000
LOG(X)	0.077981	0.021948	3.552954	0.0045
14.60805 <= LOG(Y) < 14.76714 -- 6 obs				
C	12.89435	0.653723	19.72449	0.000
LOG(X)	0.128051	0.048147	2.659584	0.0222
14.76714 <= LOG(Y) -- 3 obs				
C	-2.5905	31.88996	-0.08123	0.9367
LOG(X)	1.242292	2.250394	0.552033	0.592
R-squared	0.994267	Mean dependent var		14.09208
Adjusted R-squared	0.988534	S.D. dependent var		0.810934
S.E. of regression	0.086836	Akaike info criterion		-1.74371
Sum squared resid	0.082945	Schwarz criterion		-1.15128
Log likelihood	32.0527	Hannan-Quinn criter.		-1.59472
F-statistic	173.4225	Durbin-Watson stat		2.037493
Prob(F-statistic)	0.000			

Source: Prepared by the researcher based on the statistical software (EViews, 12)

Third: Diagnostic Tests

1. **Autocorrelation:** Based on the Durbin-Watson statistic, which was 2.037, and referring to the critical values of the statistic at (K=1, N=23) and at a 5% significance level (DU=1.437, DL=1.257), the results showed that it is greater than DU=1.437 and close to 2. Therefore, we reject the hypothesis of the presence of autocorrelation.
2. **Heteroscedasticity:** Based on the ARCH test and the F-statistic, the results showed that it is not significant at the 5% significance level. Therefore, we reject the hypothesis of the presence of heteroscedasticity. See Table (4).

Table (4) Heteroscedasticity Test

Heteroskedasticity Test: ARCH			
F-statistic	**0.33183**	**Prob. F(1,20)**	**0.571**
Obs*R-squared	**0.359056**	**Prob. Chi-Square(1)**	**0.549**

Source: Prepared by the researcher based on the statistical software (EViews, 12)

CONCLUSIONS

1. The results of the Bai-Perron sequential test for threshold values indicate the presence of five thresholds for the dependent variable (Y) when testing for multiple structural breaks.
2. At the first threshold, when the commodity export rate is less than (LOG(Y) < 13.29349), a 1% increase in patents in China leads to a 0.714% increase in commodity exports.
3. At the second threshold, where the commodity export rate in China is (13.29349 <= LOG(Y) < 14.01473), a 1% increase in patents leads to a 0.563% increase in commodity exports.
4. At the third threshold, when the commodity export rate is (14.01473 <= LOG(Y) < 14.45651), for every 1% increase in Chinese patents, commodity exports increase by 0.378%.
5. At the fourth threshold, when the commodity export rate is (14.45651 <= LOG(Y) < 14.60), a 1% increase in patents in China leads to a 0.07% increase in commodity exports.
6. At the fifth and final threshold, when the commodity export rate is (14.60805 <= LOG(Y) < 14.76714), the relationship is positive, and a 1% increase in patents in China leads to a 0.128% increase in commodity exports.
7. The general conclusion for all thresholds shows that technological innovations, represented by patents, have a positive impact on commodity exports in China across all periods. However, the strength of this impact varies, and this variation follows the export rate. The impact is greater at low to medium export rates and gradually decreases with increasing export rates until it reaches a saturation point, after which it begins to improve slightly at higher levels.

RECOMMENDATIONS

1. Policymakers at the first threshold should increase spending on research and development and enhance their investments in technological innovation, especially when export levels are low, as patents at this stage can significantly contribute to increasing exports.
2. It is necessary to direct investments in technology cautiously at the second threshold. Although innovation still has a positive impact on exports, this impact is less strong compared to the previous stage. This stage requires policymakers to direct technology investments carefully to ensure maximum benefit, such as improving the quality of patents rather than simply increasing their number.
3. Focus on improving product quality and diversification and searching for new markets at the third and fourth thresholds instead of focusing on technological change, as the impact of patents in these two stages has begun to decline.
4. It is necessary to continue innovating at the fifth threshold but with balance, with a focus on other strategies to increase exports, such as investing in improving new products and services, as well as developing distinctive marketing strategies that may help exploit the slight improvement in the impact of patents on Chinese exports.
5. Chinese authorities should conduct periodic analyses of the impact of patents on exports across all stages and adjust strategies at each stage based on the results.

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